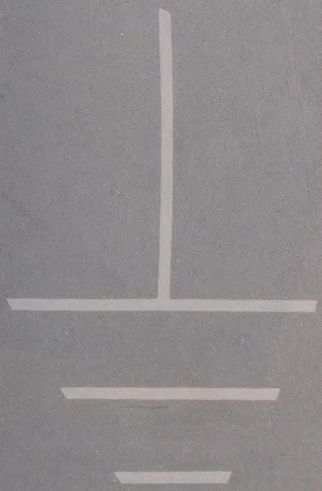
Earth Resistivity Tests With

Four Point
Electronic
vibroground®



MODEL 293 A

MANUAL 21076

ASSOCIATED
RESEARCH, INC.®

Model 293A

The Model 293A VIBROGROUND ranges are 0-1/10/100/1,000/10,000 ohms. The Model 293A resistivity range is more than 20 million ohms per cubic centimeter at 10 feet or greater probe spacing.

TABLE OF CONTENTS

SECTION I INTRODUCTION 1

SECTION II OPERATION 3

2-1 Principles of Operation 3
2-2 Set-up for Operation 5
2-3 Determination of Resistance 6
2-4 Earth Resistivity Measurement 7
2-5 Man-Made Ground Resistance Measurement 11
2-6 Circuit Resistance Measurement 16

SECTION III MAINTENANCE 17

3-1 Batteries 17
3-2 Vibrator 18
3-3 Condensers 18
3-4 Resistors 18
3-5 Balancing Meter 19

METRIC CONVERSION TABLE 20

The metric equivalents of all dimensions in this Manual are shown on the bottom of each page or adjacent to US measurements.

SECTION I

INTRODUCTION

1-1. This handbook covers operation and service instructions applicable to the 293A VIBROGROUND. This instrument is a self-contained solid state vibrator, battery powered unit which is capable of measuring earth resistivity or the true resistance to earth of man-made grounds, irrespective of the earth's resistance and condition. It is not affected by the resistance of the auxiliary probes or leads. Polarization effects are reducted to a minimu. Stray A.C. or D.C. currents in the earth do not detract from its accuracy. No outside power source is necessary. Its accuracy is not influenced by the accuracy of the indicating meter but is dependent upon the accuracy of a calibrated resistor.

1-2. Four Electrode Method, for determination of average earth resistivity. The ranges provided in the instrument make possible accurate soil resistivity measurements from 0 to 19,150,000 ohms per cubic centimeter at 10 ft. or greater spacings. Current density determinations are also possible.

10 feet = 3 meters

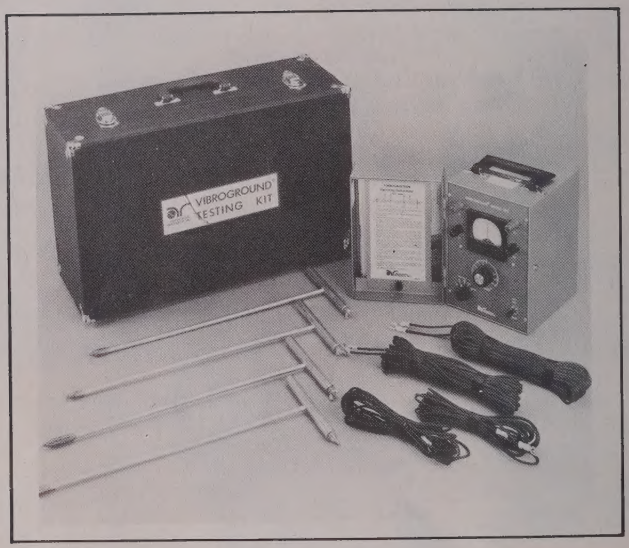


Figure 1-1 — Model 293A VIBROGROUND with #18533 Testing Kit

1-3. Three Electrode Method, for the measurement of resistance to earth of man-made grounds, anode resistances, polarization effects.

1-3.1 Two Electrode Method, for the measurement of circuit resistance.

1-4. The model 293A VIBROGROUND is manufactured by Associated Research, Incorporated.

SECTION II

OPERATION

2-1. PRINCIPLES OF OPERATION.

2-1.1. The Vibroground works on a null-balance principle of operation. The voltage drop developed by a current flowing through the unknown ground resistance is measured by comparing it to a portion of the voltage drop developed by that same current flowing through a calibrated potentiometer.

2-1.2. The instrument consists of a power supply, a current supply circuit and a measuring circuit. The power supply changes the low DC battery voltage (B) by means of a 97 CPS solid state vibrator (V) to an alternating current, which is fed to the primary transformer T_1. This voltage is stepped up to 125 volts AC in the secondary of T_1. In the current supply circuit, the secondary of the transformer T_1 is connected in series with a calibrated potentiometer and terminals C_1 and C_2 which connect to the two current electrodes (driven into the earth). The resistance of the earth between these two current electrodes completes the circuit.

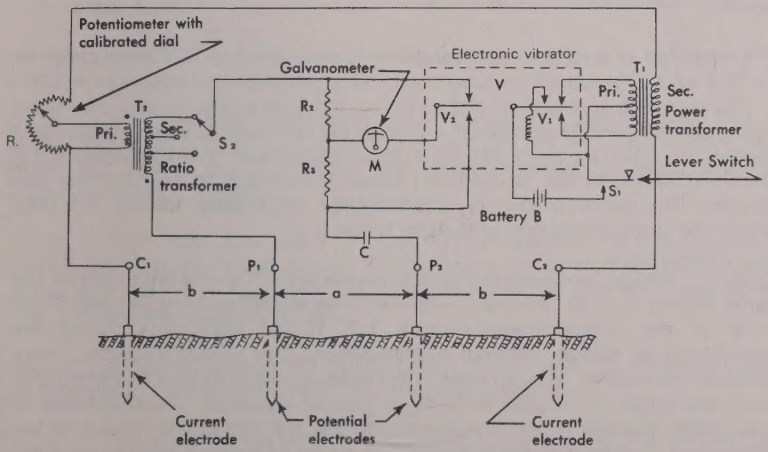


Figure 2-1 — Simplified schematic wiring diagram of Model 293A VIBROGROUND.

2-1.3. The measuring circuit consists of a secondary of the ratio transformer T_2 and its associated range selector switch S_2, two metering resistors R_2 and R_3, the galvanometer M and a blocking capacitor C (to prevent stray DC entering the measuring circuit), and two terminals P_1 and P_2 which connect to the two potential electrodes (driven into the earth between the two current electrodes). The resistance of the earth between these two potential electrodes completes the circuit.

The current flowing between the two current electrodes causes a voltage drop across the ground resistance between the two potential electrodes. This voltage drop causes a current flow in the measuring circuit. The current flowing through the calibrated potentiometer causes a voltage drop which is fed to the primary of the ratio transformer. This induces a voltage drop in the secondary of the ratio transformer, also causing a current flow in the measuring circuit. This current tends to cancel the current due to the voltage drop across the ground resistance. When the calibrated potentiometer and selector switch are adjusted so that the two currents exactly cancel, the galvanometer will indicate balance by resting in the zero position. The resistance reading on the calibrated dial of the potentiometer, multiplied by the range switch setting, then gives the value of the earth resistance between the two potential electrodes connected to P_1 and P_2.

2-1.4. Since there is no current flowing in the measuring circuit at balance, the resistance of the potential leads has no effect on the reading. Since the same current that flows through the ground causes the voltage drop on the potentiometer, the resistance of the current leads connected to C_1 and C_2 are also relatively unimportant. Since the meter current is rectified by the synchronous vibrator at 97 CPS, only current at that particular frequency can cause a meter indication. The unit is therefore independent of any stray 60 cycle power line or ground currents. Because of the blocking capacitor C in the potential circuit, stray DC ground voltages have no effect on the readings either.

The detection of zero potential condition is accomplished in Vibrogrounds by the use of a D'Arsonval galvanometer. This galvanometer has been selected for its ruggedness, accuracy and extreme sensitivity. Electrically the instruments are designed to withstand a substantial overload in their circuits for a short time. They are protected by a stepped sensitivity shunt incorporated in the Test Switch circuit to facilitate coarse adjustment to approximate zero balance. The galvanometer is automatically electrically locked for extra protection of its pivots during transportation.

2-1.5. Ranges are selected by a separate switch at the lower left of the panel (Figure 2-2, 2). Special design features permit reading, on the single scale of the potentiometer (Figure 2-2, 1). All resistance values are determined by simple decimal multiplication. The ranges provided make possible the reading of earth resistivity measurements from 0 to 19,150,000 ohms per cubic centimeter at 10 ft. or greater spacings. The resistance of man-made grounds under average conditions fall within the ranges of the instrument. Resistance measurements of single or multiple anodes installed in the earth, also fall within the ranges of the instrument.

10 feet = 3 meters

2-1.6. Condensed field operating instructions are contained in the instrument cover.

2-2. SET-UP FOR OPERATION.

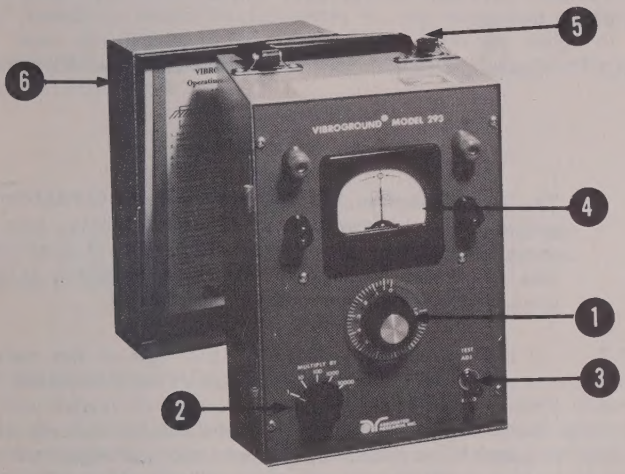


Figure 2-2 — Panel view of Model 293A VIBROGROUND

1. Meter Balancing Control and OHMS Indicator
2. Range (MULTIPLY BY) Switch
3. TEST Switch
4. Galvanometer
5. Carrying handle
6. Cover and Storage Compartment

2-2.1. With the instrument lying in front of you so that the cover lock is at its right side, unlatch and open lid. To remove lid, push away from you which will release the slip hinges. The lid can then be removed from the instrument during testing.

2-2.2. For field test work a Test Kit is available. It consists of a partitioned leatherette case with a compartment for either VIBROGROUND model and includes: four 18" T-shaped ground prods, two test leads 20 ft. long and two test leads 50 ft. long.

2-2.3. Depending upon the measurement to be made, the instrument will be connected in accordance with the following paragraphs.

2-2.4. To close up the instrument, repeat in reverse the process referred to above.

18 inches = 46 cm 20 feet = 6.1 m 50 feet = 15 m

2-3. DETERMINATION OF RESISTANCE.

2-3.1. It is advisable to begin testing with the range selector switch (Figure 2-2, 2) set in the high range or "10000" position. The potentiometer knob should be turned to its most clockwise position as shown in (Figure 2-2, 1). This setting provides resistance of 10,000 ohms on the internal resistance leg of the bridge.

2-3.2. Operate the TEST Switch (Figure 2-2) to the ADJ position.

NOTE

The TEST Switch should always be operated to ADJ during preliminary adjustments. This reduces sensitivity of instrument and protects galvanometer against violent overswings. When operated to READ, maximum sensitivity is then employed for final potentiometer adjustment.

2-3-3. If the pointer deflection is to the right of the meter dial, the resistance is within the measurement range of the instrument. The potentiometer knob should be slowly turned counter-clockwise until the meter pointer is centered. At this point observe the potentiometer scale and index mark on the panel. If it is positioned at a point approaching zero, the resistance range is too high and the range selector switch should be shifted to the next lower or "1000" position. With the range selector switch in this position, and the potentiometer knob in the extreme clockwise position, again operate the TEST switch and adjust the potentiometer knob as before. If the pointer on the meter cannot be centered again until the knob indicates a position approaching zero the range is again too high and the next lower range should be worked as described previously. If the meter pointer cannot be centered within the "100" range, again repeat the operation with the range selector switch in the "10" or "1" position.

2-3.4. The function of the range selector switch is to furnish various multiplier circuits to permit reading of ohmic values from 0-10,000 in the "10,000" position, 0 to 1,000 when in the "1,000" position; 0 to 100 when in the "100" position; 0 to 10 when in the "10" position and 0 to 1 when in the "1" position. Thus assuming that the potentiometer knob pointed to .4 indication on the panel scale with the range switch in the "1000" position, then the ground resistance would be 400 ohms. If the same potentiometer reading were obtained with the switch in the "100" position, the resistance would be 40 ohms; with the range switch in the "10" position resistance would be 4 ohms; with the range switch in the "1" position, the resistance would be .4 ohms.

2-3.5. As soon as the pointer of the meter has been centered in any of the ranges, operate the TEST switch to the READ position for full sensitivity. Again center the meter pointer with the switch in this position by re-adjustment of the potentiometer knob. Assuming that the meter pointer

was able to be centered with the range switch in the "10" position and the potentiometer knob pointer set at the ".12" indication on the panel scale, the resistance measurement being made would be 1.2 ohms. If the potentiometer knob were located halfway between the ".12" and the ".14" at the time the meter pointer were centered and the range switch in the "10" position, then the ground resistance would be 1.3 ohms. In this way it is possible to accurately read the resistance of any value within the range of the VIBROGROUND by interpolation of the setting of the potentiometer pointer and the range switch.

NOTE

It will be impossible to observe any meter pointer deflection if external electrode circuits are open due to disconnected or broken leads.

2-4. EARTH RESISTIVITY MEASUREMENT.

2-4.1. In the field of corrosion studies pertaining to buried objects and conducting or circuit carrying materials, which come in contact with the earth, the resistivity of such earth is of prime importance.

2-4.2. The use of earth resistivity measurements in Geophysical Prospecting and the determination of subsurface strata is a well-known and accepted practice. Variation of electrode spacings, and configuration, over the area under consideration provides a wealth of information. The problems of such measurements are those of the Geophysist. No attempt is being made to cover this highly specialized field in this manual.

2-4.3. Although several methods have been employed to determine earth resistivity the most satisfactory method has resulted from the use of an instrument such as Model 293A VIBROGROUND. With this instrument the earth resistvity can be determined in ohms per unit volume generally accepted as ohms per cubic centimeter.

2-4.4. The average earth resistvity of a given area can be most easily measured by the use of the 293A VIBROGROUND, four electrodes and the necessary connecting leads. Where desired, an auxiliary test kit No. 18533 consisting of a suitable carrying case, four 18" rods, two short leads of equal lengths and two long leads of equal lengths, can be supplied at extra cost. (See Figure 1-1.) In determining average earth resistivity by the Four Electrode Method, the spacing "a" between electrodes P_1 and P_2 controls the average depth to which the average earth resistivity is being determined. (Figure 2-3.) It is therefore essential that this spacing be maintained accurately at all times and particularly where many readings are being taken over a wide area at spacings as determined by the depth penetration to which it is desirable to take readings.

18 inches = 46 cm

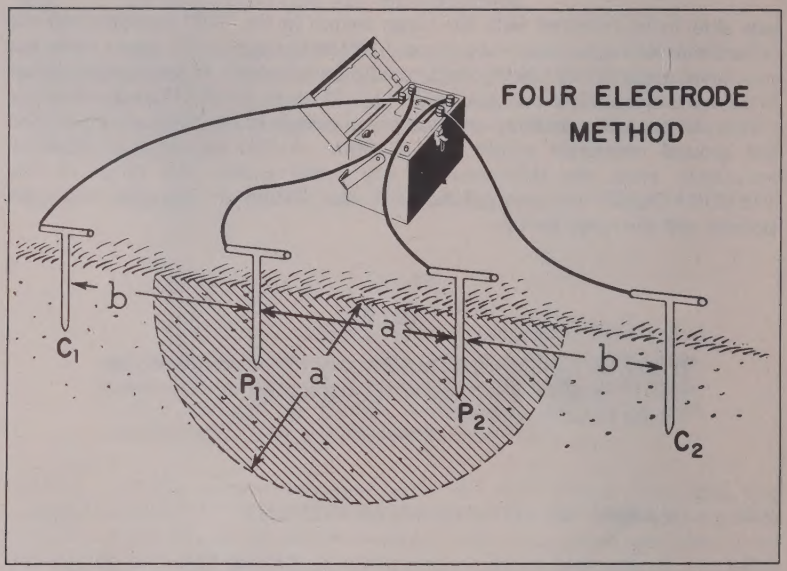


Figure 2-3 — Diagram of proper test probe placement for four electrode method.

2-4.5. The calculated soil resistivity (P) will be the average to a depth "a" when "b"="a" (Fig. 2-3). If distance "b" is greater than "a", the resistance reading (R) will decrease. When "b" is less than "a", the resistance reading (R) will be greater than when "b"="a". For conditions where "b" does not equal "a", the soil resistivity (P) in ohms per cubic centimeter is correctly calculated by the formula:

$$P = \frac{95.76\ bR}{1 - \frac{b}{b+a}} \text{ (with dimensions in feet)}$$

2-4.6. Soil resistivity in ohms per cubic centimeter (P) equals 2 pi times the distance between the potential electrodes P_1 and P_2 in centimeters (a) times the reading of the instrument in ohms (R).

$$P = 2\ \pi aR \text{ (with "a" in centimeters)}$$
$$P = 191.5\ aR \text{ (with "a" in feet)}$$

For the recommended condition with "b"="a", the following table is provided. Readings taken at greater spacing can be obtained by applying the formula as given above.

1 foot = 30.5 cm

Distance between P_1 and P_2		Multiplier times R in ohms
in feet	in meters	
1	0.305	191.5
2	0.610	383.0
3	0.910	574.5
4	1.22	766.0
5	1.52	957.5
6	1.83	1149.0
7	2.13	1340.5
8	2.44	1532.0
9	2.74	1723.5
10	3.05	1915.0

The average soil resistance or earth resistivity between P_1 and P_2 is obtained with no electrode contact resistance included.

2-4.7. In conjunction with cathodic protection, current density can be readily determined by the use of the four electrode method wherein measurement of resistance between two potential electrodes at right angles to the structure is taken. Then measure the potential difference between the same two electrodes with a potentiometer voltmeter. Calculate current circulating in the area under test by applying Ohm's Law.

2-4.8. In the VIBROGROUND, the measured resistance in the four electrode method is that of a hemisphere of soil of radius "a" (Figure 2-3), measured from two points on the circumference of the hemisphere and distance "a" apart. The outside current electrodes (C_1 and C_2) introduce a current into the soil. This current creates an I R potential drop through the soil which is contacted by the potential electrodes, and is counter-balanced internally in the instrument by a current through a calibrated variable resistor.

2-4.9. If the underground pipe line were within the field measured by the potential electrodes it would offer a lower resistance path between them than the earth itself. Thus the resistance reading would be low and erroneous. The potential electrodes should be at least 1/2 "a" from the pipe line.

2-4.10. The only effect of the current electrodes being too close to the pipe line would be to make the potential indications weaker and thus harder to determine a null balance. In this case the resistance reading would not be erroneous, only more difficult to obtain. It is always better practice to place the measuring electrodes in a line perpendicular to the pipe line, rather than in a line parallel to it.

2-4.11. Although earth resistivity measurements are usually considered in connection with cathodic protection, the additional advantages of this instrument for the measurement of anode resistance should not be overlooked. These readings may be obtained by the Three Electrode Method wherein terminals C_1 and P_1 are considered as one connection but to be used together by separate leads to the anodes (see Figure 2-4). The distance "b"

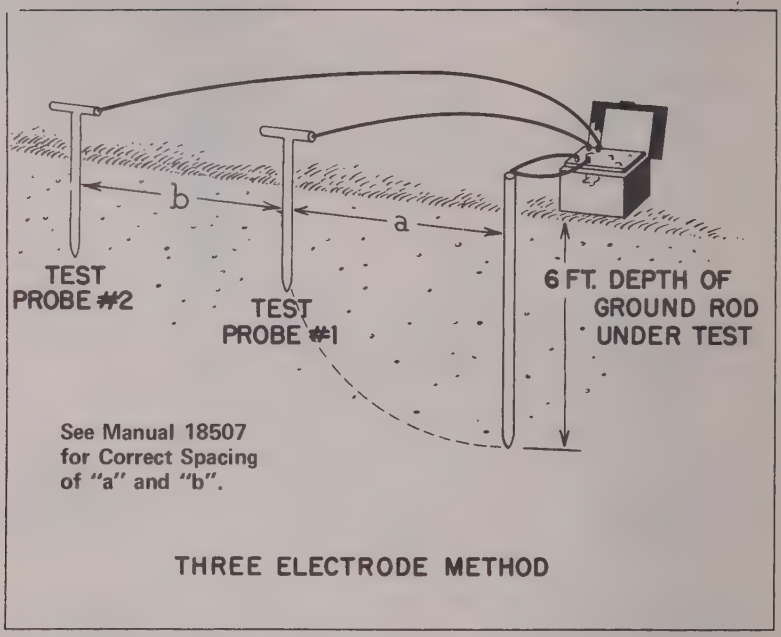


Figure 2-4 — Diagram of proper test probe placement for three electrode method.

affects the readings in the same manner as with the Four Electrode Method. See Manual 18507 for correct placement. Be certain that C_1 and P_1 have separate leads to the anode being measured, otherwise the resistance of leads to C_1 will be included.

2-4.12. Using this method the internal resistance of the soil, soil contact resistance of anode and internal resistance of anode will be obtained. Soil contact of electrode #1 is not included in readings which result from this measurement.

2-4.13. To determine polarization effects, the Three Electrode Method can be used before and after cathodic protection has been applied. Resistance measurements can be made with the Model 293A VIBROGROUND while cathodic protection is being applied.

2-4.14. Circuit resistance between anodes can be obtained by using Model 293A VIBROBROUND as 2 electrode instrument (Figure 2-5). By using the instrument in this manner, be certain that C_1 and C_2 have separate leads to anodes from those used for P_1 and P_2, otherwise the resistance of these leads will be included. When using the Model 293A in this manner, it is possible to obtain the internal resistance of both anodes, soil contact resistance of both anodes, and soil resistance between anodes to a depth equal to "a".

6 feet = 1.83 m

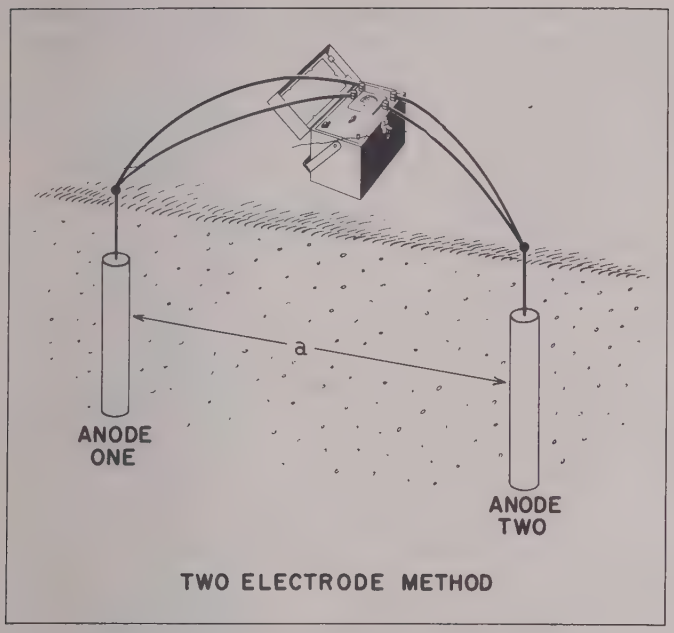


Figure 2-5 — Diagram of proper test probe placement for two electrode method.

2-5. MAN-MADE GROUND RESISTANCE MEASUREMENT.

2-5.1. In electricity, the earth is considered to be the point of lowest potential. Therefore, any material capable of conducting an electrical current, when connected to the earth by means of a conductor, also is at zero potential since any voltage existing in the material will be carried to the earth. Thus, if a power transmission tower, motor frame or metallic conduit is sufficiently well grounded, it cannot maintain a potential which might be established either through direct connection to a power source or by induction.

2-5.2. The quality of a man-made ground varies greatly depending upon the characteristics of the earth itself at the point at which the man-made ground is actually established. Clay and mud generally provide the best ground connections since they are dense in structure and generally contain sufficient moisture and metallic salts to render them conductive. Loosely packed sand or rock will be less conductive than the same material which is tightly packed. The amount of moisture in earth in which a ground is being established is of great importance. A relatively high moisture content is extremely desirable. The presence of mineral salts will also aid in the establishment of a good man-made ground. See Manual 18507.

2-5.3. The maximum of ground resistance allowable for different purposes varies. A good grounding system limits system-to-ground resistance to an acceptably low value. This protects personnel from a dangerously high voltage during a fault in the equipment. Furthermore, equipment damage can be circumvented by using this ground current to operate protective devices. Statistics vary widely concerning what may be considered a dangerous voltage. This depends largely on body resistance and other conditions.

2-5.4. In the measurement of ground resistance with most instruments it is necessary that the presence of stray A.C. or D.C. current in the ground under test be eliminated from calculations before establishment of an accurate ground resistance reading is made. In the VIBROGROUND this has been done by means of the circuit employed and readings of ground resistance are accurate without the requirement for any further calculation. It is necessary in all cases to be sure to isolate the made-ground under test. To do this, the user of the VIBROGROUND must make sure that the unit to which the ground is attached is not in any way attached to another ground. The best way to accomplish this is to disconnect the ground which is to be tested from its connection to the equipment which it is serving as a ground and make test of the ground itself while it is disconnected. As a further check for other ground connection of the unit to which the ground is normally attached, the VIBROGROUND should be connected to the equipment and a reading taken before the tested ground is reattached. If the test shows a relatively low ground resistance, the test would indicate the presence of another ground connection being made to the equipment either accidentally or by design. The presence of a secondary ground will in no way be detrimental and is recommended especially in cases where large voltages are encountered.

2-5.5. The VIBROGROUND is not affected by the resistance of either the test leads or the test probes used for the test. For simplicity, test kit No. 18533 (Figure 1-1) is recommended for earth resistivity measurements and test kit No. 18503 for measurement of man-made grounds.

2-5.6. In testing ground resistance it must be remembered that while the resistance between the actual ground and the grounding medium (pipe or rod, etc.) is negligible, the conditions set up in the establishment of the ground must be taken into careful consideration if an accurate test is to be made. The earth around the grounding point may be considered as a series of uniformly concentric (if the earth is of homogenous structure) sections or irregularly shaped sections (if homogeneity is not found). The diagram (Figure 2-6) shows how these sections of uniform potential and consequent resistance will exist as they surround a ground rod. The largest drop in potential will occur in a minimum section immediately surrounding the man-made ground. This effect lessens rapidly with the addition of succeeding sections, becoming fairly constant in a short distance. In (Figure 2-4), where a simple rod is driven to a depth of six feet, it is necessary that the test probes be placed in the ground at a distance in excess of the depth of the driven ground if an accurate measurement of resistance is to be made. The reason for this lies in the radial effect of the depth of the ground on the earth surrounding the rod

6 feet = 1.83 m

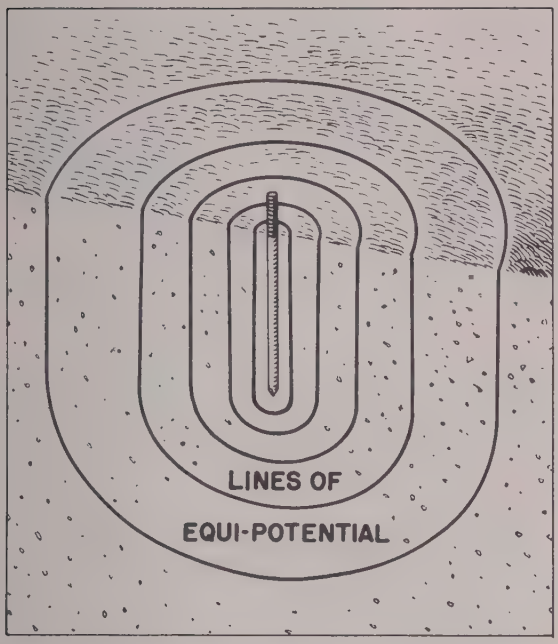


Figure 2-6 — Diagrammatic sketch of lines of equi-potential in homogenous ground.

or pipe. Whenever the depth of the driven ground to be measured is unknown, always allow more than enough distance between the first driven test probe and the ground under test to insure against this radial effect. In actual practice, the operator must be careful to get the two test probes properly spaced and positioned to avoid possible inaccuracies in reading. A good rule is to place the probes at uniformly spaced distances and on a straight line away from the ground under test. (See Manual 18507).

2-5.7. Often metal masses are buried to form a better ground. If such grounds are being tested, it will be necessary to determine the effective area of these grounds and then place the test probes outside of the radius formed by the depth and outside limit of the buried mass as shown in (Figure 2-7).

2-5.8. At times grounds will be formed by a grid of driven or buried grounds as shown in (Figure 2-8). In such instances it is necessary that the test probes be placed outside the actual ground area after this area has first been thoroughly established as to location and size. For greatest accuracy in such cases, place the current electrode 2 a distance from the ground under test equal to five times the length of the longest diagonal of the area covered by this ground. The potential electrode 1 should then be placed near the center. Greater electrode spacings, if possible, will afford greater accuracy of reading.

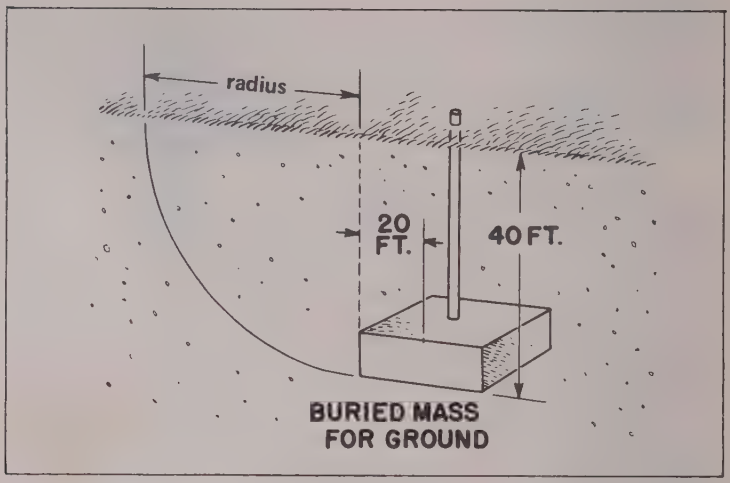


Figure 2-7 — Diagram of method of determining proper distance for test probe placement when using buried mass for ground.

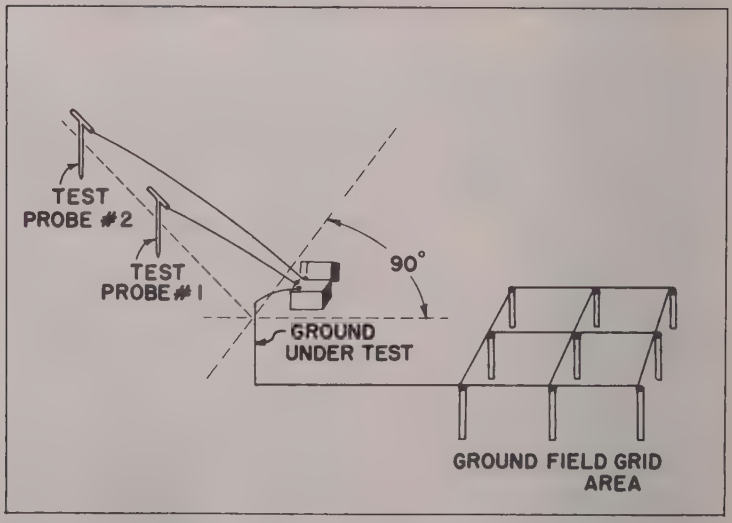


Figure 2-8 — Diagram of placement of test probes for testing "grid" ground field.

20 feet = 6.1 m 40 feet = 12.2 m

2-5.9. In testing a man-made ground it is often impossible to determine accurately soil conditions of the ground. Often the location of a buried ground bed is indeterminate. Should abnormally low resistances be encountered, a safe check is to increase the spacings of the auxiliary test probes until a point is reached where the readings observed do not appreciably change.

2-5.10. In the measurement of a power line ground for instance, always set the test probes on a line which is at right angles to the direction of the line. If the ground of a corner pole of such a line is being tested, first try to set the probes on the bisector of the outside angle formed by the line as shown in (Figure 2-9). If this is impossible, then the probes should be placed on the line forming the bisector of the inside angle. The reason for such placement is to eliminate any possibility of inaccuracy through induction.

2-5.11 It will oftentimes be found advisable to employ the use of a previously established ground such as a water system or other easily available and well established grounds. This is particularly useful in checking grounds on equipment located inside buildings. When such procedure is found to be advisable then the Model 293A instrument would be used as a 2 electrode instrument by connecting C_1 and P_1 together and C_2 and P_2 together and in turn, connecting them to this common ground as illustrated in (Figure 2-10).

2-5.12. If absolutely accurate readings are desired, P_1 and C_1 should be connected to the grounds under test by separate leads whereas terminals P_2 and C_2 may be connected together and then to the low resistance ground. Readings may then be taken as described in paragraph 2-5.11.

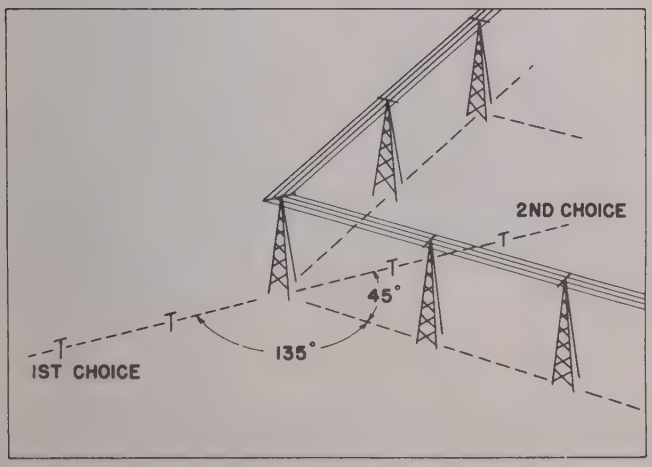


Figure 2-9 — Diagram of test probe placement for testing corner tower of power line to avoid induction error.

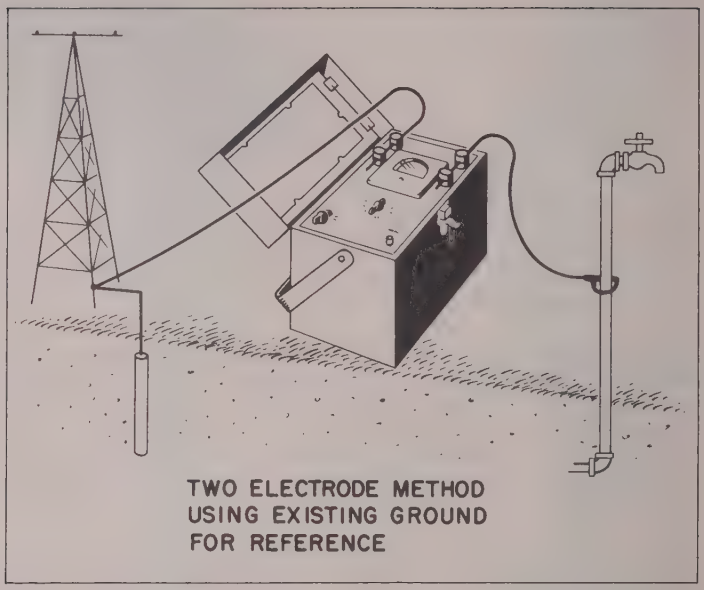


Figure 2-10 — Two electrode method using existing ground for reference.

2-5.13. When the nature of the ground prohibits the driving of test probes into the surface, a satisfactory pair of auxiliary grounds can be made by use of two 1 ft. square pieces of metal which are placed on the surface of the earth and firm contact established between earth and plates. Use of wet dirt and brine mixture is recommended to establish this contact with the hard surface. Test leads are then attached to plates and connected in the usual manner to the VIBROGROUND. Usually any grounds of this type will be of high resistance unless the rock or hardpan has high mineral content.

2-6. CIRCUIT RESISTANCE MEASUREMENT.

2-6.1. Model 293A VIBROGROUND may be used for measuring approximate resistance of coils, transformers, resistors or other items comprising resistance within the range of the instrument. To obtain these readings the two-point method is employed by shorting binding posts P_1 and C_1 together and binding posts P_2 and C_2 together and connecting the resistor under test between these two pair of shorted binding posts.

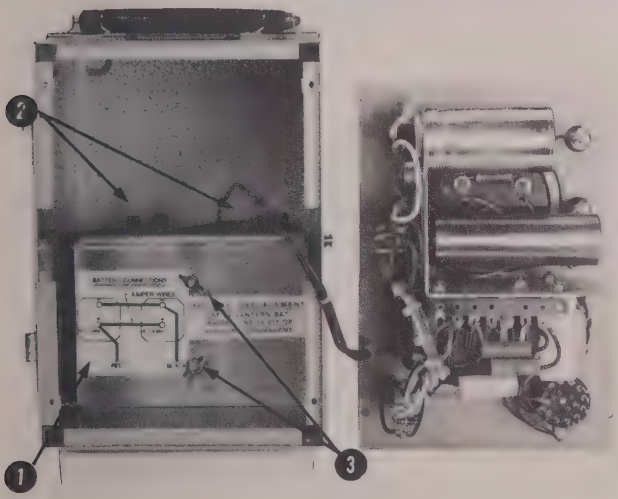
1 foot = 30.5 cm

SECTION III

MAINTENANCE

3-1. BATTERIES.

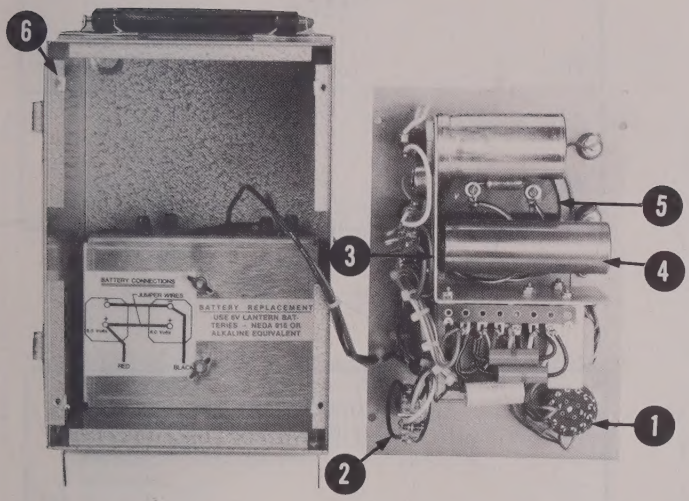
3-1.1. Model 293A VIBROGROUND is made so as to require a minimum of maintenance. In general usage, it will only be required that the batteries be replaced from time to time as their power deteriorates through time or use. If the vibrator ceases to operate or readings become erratic, it can usually be assumed that the batteries are exhausted. As accuracy and operation of the instrument is independent of normal battery voltage, batteries may be used until no longer able to actuate vibrator. To replace the batteries, remove the four screws (7, Figure 3-2) and lift out the entire assembly as shown in (Figure 3-1). Remove the thumb nuts and clamp plate (4), and batteries (3). Disconnect the battery wires and connect them to new batteries; Use the



1. Battery Connection Diagram
2. Batteries
3. Battery Clamp with Wingnuts

Figure 3-1 — Battery Compartment View of the VIBROGROUND

Battery Connection Diagram as a guide. Use fresh Duracell ID 9150, Eveready 528, or equivalent batteries. Replace the batteries, clamp and thumbnuts making certain that the battery terminals are oriented as shown in (Figure 3-1). Replace the assembly into the case and secure with the four screws.



1. Range Selector Switch
2. Test Switch
3. Component Chassis Assembly
4. Electronic Vibrator
5. Meter
6. Battery Compartment Screws Holes (4)

Figure 3-2 — Under Panel View of the VIBROGROUND

METRIC CONVERSION TABLES:

To convert from FEET	
To	Multiply by
Centimeters	30.48
Meters	0.3048

To convert from INCHES	
To	Multiply by
Centimeters	2.54
Meters	0.0254

vibroground

Warranty

VIBROGROUND instruments are guaranteed free from defects in workmanship and material for one year from date of shipment provided Owner's Registration Card is returned within fifteen days from receipt of unit and there is no evidence of tampering or abuse.

This Warranty does not cover tubes, batteries, or accessories not of our manufacture.

Any unit found defective under this guarantee will be repaired or replaced free of charge if returned to the factory PREPAID and insured.

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